Long Range Ocean Acoustic Propagation Modeling

Kevin D. Heaney
ORINCON Corporation, 4450 N. Fairfax Dr. Suite 400, Arlington VA, 22044
phone: (703) 351-4440 fax: (703) 351-4446 email: kheaney@east.orincon.com

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LONG-TERM GOALS

Understand the physical processes affecting long-range ocean acoustic propagation and its impact on signal processing and tomography. Processes of interest are down-slope mode conversion and scattering due to sea-mount features, internal and surface waves.

OBJECTIVES

Explore basic research issues that are relevant to the Navy. Examine the impact of bathymetric and oceanographic scattering on signal coherence in both time and space.

APPROACH

Interact with the basic research community (ONR sponsored long-range acoustics program NPAL, led by Scripps Institution of Oceanography and the Applied Physics Laboratory-University of Washington) and the Navy research community (APB program and the Submarine Security Program) to determine areas of basic research that is applicable to Navy signal processing issues. Investigate areas of interest and examine anomalies in the observed data.

WORK COMPLETED

Since 1996 the ATOC Group [1] has been transmitting sound across ocean basins recording acoustic time series from a variety of arrays. One significant source of data is the SOSUS system, which consists of a US Navy network of underwater hydrophone arrays. For the deep-water arrays, acoustic energy is received on these arrays at arrival times and depths that are inconsistent with ray-theory predictions. The arrival time of this energy corresponds to water-borne acoustic rays that should turn several hundred meters above the reported depths of these arrays. This phenomenon, coined the Acoustic Shadowzone Phenomena (ASP), by Brian Dushaw [2] has been observed in several oceans and for a variety of experiments. Internal wave induced acoustic fluctuations has been investigated as a possible mechanism for scattering acoustic energy in depth but it has been found to be to week to explain the observations.

Two possible explanations of this phenomenon were investigated. Last year we examined the affect of near-source bathymetric interaction [3]. Near source scattering leads to a significantly different arrival pattern in deep water than the case where the path is all deep water. This explanation does not work for one particular observation of the ASP however. During the Alternate Source Test (AST) of the ATOC program, the source was suspended in the water column in deep water. For this experiment

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14. ABSTRACT
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15. SUBJECT TERMS

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arrivals in the acoustic shadow where observed. Addressing these anomalous arrivals was the subject of this year's research. Our approach is to look at simulations and basic analytic acoustics to see if there is another explanation of the observations.

RESULTS

We begin looking at the expected arrival pattern (in time/depth space) for a broadband (60-90Hz) acoustic transmission at a range of 200km. The environment is range-independent with a sound speed field taken from CTD measurements in the Pacific Ocean Northeast of Hawaii.

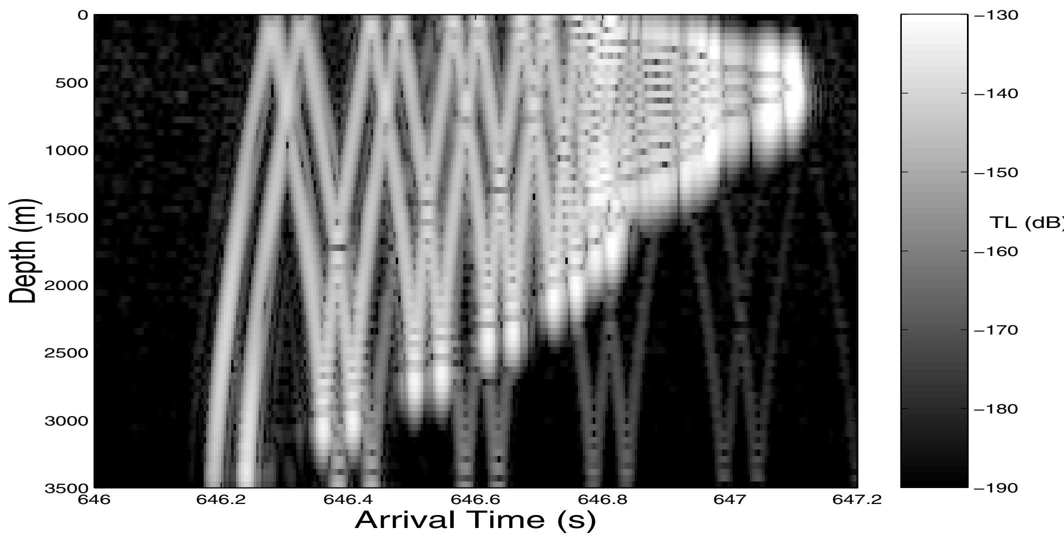

FIGURE 1. Broadband normal mode simulation at a range of 1000 km. The source depth is 900m, bandwidth 60-90Hz.

The strong early arriving doublet arrival pattern is for energy with high phase speeds corresponding to high mode numbers or high angle rays. This energy is surface interacting but refracts in deep water without hitting the bottom. The weak arriving doublet arrivals that traverse the entire water column are energy that is surface and bottom interacting. It is this energy that is the focus of this paper. These bottom grazing acoustic paths are 50-60 dB below the axial energy. We have not expected to see them because we have thought of the deep water SNR for long-range acoustic experiments to be be 30 dB. The deep mounted SOSUS arrays are in very deep water and the ambient noise is expected to be 15-20 dB lower then in the sound channel. Add this to the array gain for a beamformed horizontal array and these low level arrivals should be visible. They have a clear doublet arrival pattern with linearly decreasing energy in dB's.

To examine the nature of the propagation in this environment we look at the analytic acoustics derivable from the sound speed field. Geometric integrals over the sound speed field lead to ray cycle distances (R) and cycle times (T) and from these we can compute the group velocity vg=R/T as a function of phase speed (turning depth). These results are shown in figure 2b.

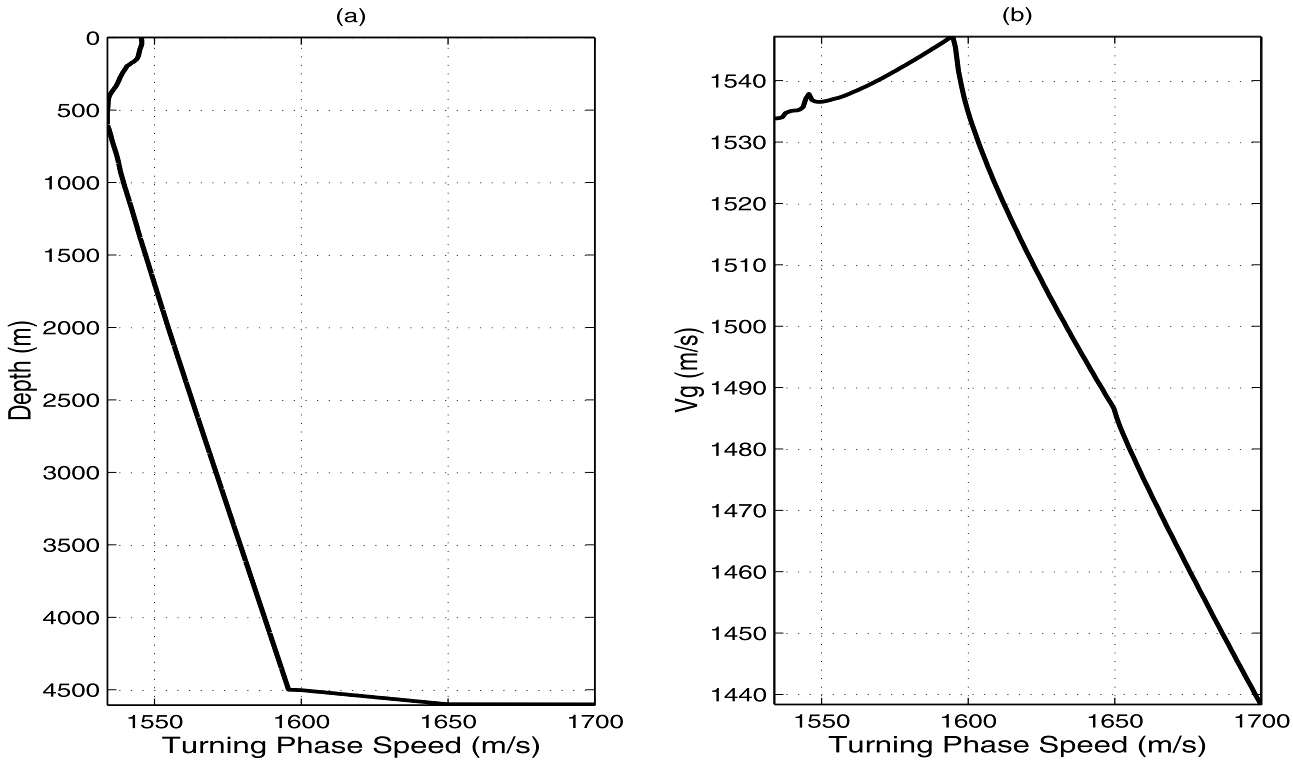

FIGURE 2. (a) Sound Speed Profile for Central Pacific. (b) Group velocity vs. Phase velocity calculation

For the region between 1480 and 1600 we have the water-born energy. This increasing group velocity with phase velocity is typical of deep water profiles. At 1595 m/s we have the sound that begins to interact with the bottom and the group speed/phase speed relations change. Now higher phase speed energy actually travels slower. We see that there is a region with a phase speed near 1600 that has group speeds corresponding to acoustic energy that is in the water column and must turn several hundred meters below the bottom because of it's lower phase speed. We propose that the energy on received on the bottom mounted hydrophones corresponds to bottom interacting energy with phase speeds on the order of 1600 m/s rather then scattered water-born energy with a phase speed of 1575 m/s. Examination of the grazing angles of these acoustic paths reveals that they graze the bottom (in this 3500m environment) at angles of 1.4, 2.5, and 3.6 degree's for the first three arrivals. These angles are very small and the reflection coefficients at these angles should be very nearly 1.

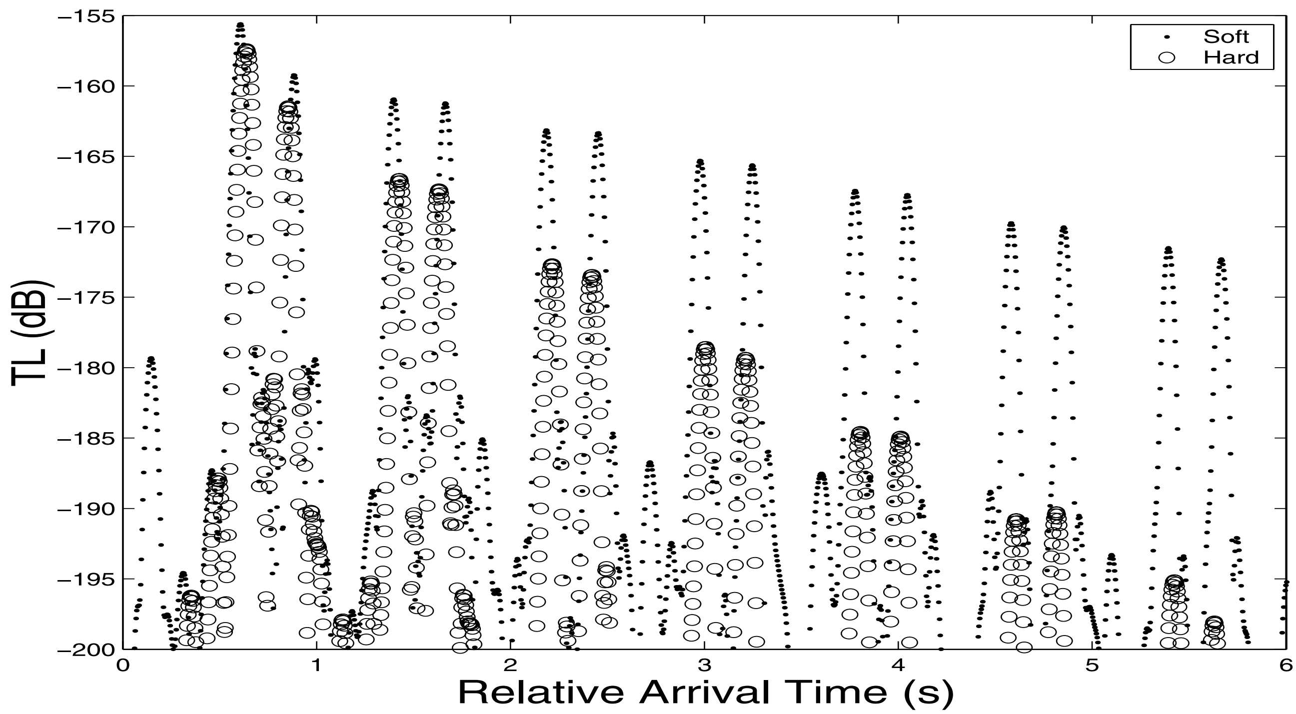

FIGURE 3. Arrival envelope for a bottom mounted hydrophone for two different geo-acoustic parameters. The soft bottom has a 100m sediment, and the hard one is sand-gravel.

In Figure 3 we show the effect of different sediment types and the effect of attenuation in the bottom is clearly seen. The attenuation in the bottom dominates how many acoustic paths will be observed.

In conclusion, we have presented an explanation of how there can be acoustic receptions on the bottom with arrival times corresponding to those of fully water-born acoustic paths. These bottom grazing acoustic paths should have enough energy to be detected on a bottom mounted horizontal line array. It must be stated that the arrival times of these ASP arrivals do correspond well with the water borne paths and that is not the case for the simple range-independent environment used for this work.

IMPACT/APPLICATIONS

Should this explanation prove to be true the use of bottom mounted receivers as tomographic receivers of opportunity will be in serious doubt. The presence of bottom interacting paths in long range receptions provides the opportunity for long-range remote sensing of basin scale geo-acoustic parameters.

TRANSITIONS

Acoustic propagation knowledge, and numerical models applicable to solving these long-range acoustic problems have been applied to other areas of Navy system performance and design.

RELATED PROJECTS

This work is closely associated with the acoustic modeling support ORINCON provides for the Submarine Security Program and the APB program.

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